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16. ABSTRACT

As people are being encouraged to walk more to reduce environmental impacts and improve public health, transportation professionals are obligated to make walking as safe as possible. To date, the dominant strategy used by state agencies to allocate safety resources is the hotspot approach, which focuses on identifying and recommending improvements for high collision concentration locations. Another strategy, the systemic approach, seeks blanket improvements that can be implemented at sites throughout the road network, based on specific roadway features that are associated with a particular crash type. This study developed a systemic approach to identify pedestrian safety problems and improvements. The process included: (a) developing a practical method to identify systemic pedestrian safety challenges throughout the state highway system; (b) providing a list of potential improvements to support practitioner decision-making; and (c) developing a prototype Microsoft Excel spreadsheet to conduct systemic pedestrian analysis and provide decision support. The outcome is a methodology to support systemic pedestrian safety efforts across the California State Highways System. The methodology is incorporated into a user-friendly Excel prototype tool to conduct systemic pedestrian efforts analyses and identify safety improvements.

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STRATEGIES FOR REDUCING PEDESTRIAN AND BICYCLIST INJURY AT THE CORRIDOR LEVEL

FINAL TECHNICAL REPORT

PREPARED BY THE
UC BERKELEY SAFE TRANSPORTATION RESEARCH AND EDUCATION CENTER
FOR THE
CALIFORNIA DEPARTMENT OF TRANSPORTATION

JUNE 30, 2017

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Executive Summary

As people are being encouraged to walk more to reduce environmental impacts and improve public health, transportation professionals are obligated to make walking as safe as possible. To date, the dominant strategy used by state agencies to allocate safety resources is the hotspot approach,which focuses on identifying and recommending improvements for high collision concentration locations. Another strategy, the systemic approach, seeks blanket improvements that can be implemented at sites throughout the road network, based on specific roadway features that are associated with a particular crash type. While the hotspot approach is reactive in the sense that it focuses on sites that have already experienced crashes, the systemic approach employs both reactive and proactive components. The hotspot approach is reactive since it uses historical crash data to identify the type of roadways that suffer from recurring safety challenges, while it is proactive since it provides a mechanism to also make improvements at sites that, while they share the same design and operational attributes, have not experienced many—or any—crashes. Therefore, it is necessary to develop a tool that can be used to identify systemic pedestrian safety problems that would benefit from blanket improvements to support pedestrian safety improvements throughout the state highway system.

The overarching goal of this study was to reduce pedestrian fatalities and injuries by developing a systemic approach to pedestrian safety challenges and improvements. This included: (a) developing a practical method to identify systemic pedestrian safety challengesthroughout the state highway system; (b) providing a list of potential improvements to support practitioner decision-making; and (c) developing a prototype Microsoft Excel spreadsheet to conduct systemic pedestrian analysis and provide decision support.

Caltrans, in partnership with the University of California, Berkeley, Safe Transportation Research and Education Center (SafeTREC) identified a set of tasks and activities to accomplish this research. The tasks included: (i) study of where systemic efforts can complement other road safety management efforts in terms of reactive vs. proactive approaches; (ii) identification of the core components of the systemic approach which led to the development of the systemic matrix; (iii) development and population of the systemic pedestrian crash matrix using available crash and roadway data; (iv) creation of customized matrices for intersection and roadway sections; (v) initiation of lists of relevant countermeasures for each matrix cell; and (vi) development of a user-friendly prototype tool in Microsoft Excel that is able to conduct such an analysis and produce a list of attributes of relevant countermeasures.

The outcome is a methodology to support systemic pedestrian safety efforts across the California state highways system. The methodology is incorporated into a user-friendly Excel prototype tool to conduct systemic pedestrian efforts analyses and identify safety improvements.

This methodology provides Caltrans with a simple to assemble, easy to interpretsnapshot of systemic pedestrian problems across the state highway system. As a result, Caltrans can develop programs to detect systemic priorities for pedestrian safety problems across a district or other scalable area. The methodology and corresponding tool can provide a list of countermeasures that are relevant for the specific safety challenge and location type, which can be used as a resource for identifying appropriate safety improvements. Ultimately, these methods and tools will lead to fewer pedestrian injuries and fatalities on the California State Highway System.

1 INTRODUCTION

As people are being encouraged to walk more to reduce environmental impacts and improve public health, transportation professionals are obligated to make walking as safe as possible. To date, the dominant strategy used by state agencies to allocate safety resources is the hotspot approach,which focuses on identifying and recommending improvements for high collision concentration locations. Another strategy, the systemic approach, seeks blanket improvements that can be implemented at sites throughout the road network, based on specific roadway features that are associated with a particular crash type. While the hotspot approach is reactive in the sense that it focuses on sites that have already experienced crashes, the systemic approach employs both reactive and proactive components. The hotspot approach is reactive since it uses historical crash data to identify the type of roadways that suffer from recurring safety challenges, while it is proactive since it provides a mechanism to also make improvements at sites that, while they share the same design and operational attributes, have not experienced many—or any—crashes. Figure 1.1 illustrates how different road safety management approaches are spread across a Reactive-Proactive continuum. Therefore, it is necessary to develop a tool that can be used to identify systemic pedestrian safety problems that would benefit from blanket improvements to support pedestrian safety improvements throughout the state highway system.
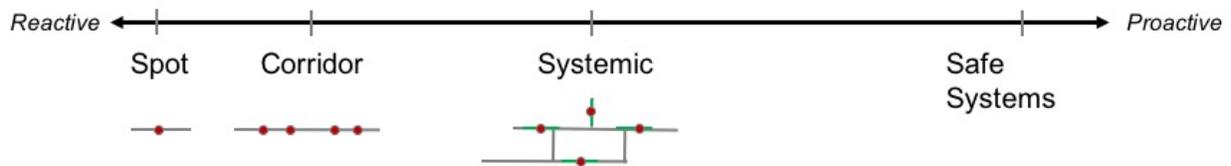
Figure 1.1. The Systemic Approach on the Reactive-Proactive Continuum
The systemic approach is reactive since it uses historical crash data to identify the type of roadways that suffer from recurring safety challenges, and it is proactive since it provides a mechanism to make improvements also at sites that while they share the same design and operational attributes, have not experienced many (or any) crashes yet.

Road safety researchers and professionals have already identified the value of the systemic approach to safety. The Federal Highway Administration(FHWA) Office of Safety has acknowledged four benefits of the systemic approach and developed the Systemic Safety Project Selection Tool (Figure 1.2) which: (i) solves an unmet need in transportation safety; (ii) uses a risk-based approach to prevent crashes; (iii) results in a comprehensive road safety program; and (iv) advances a cost-effective means to address safety concerns (FHWA, 2013).
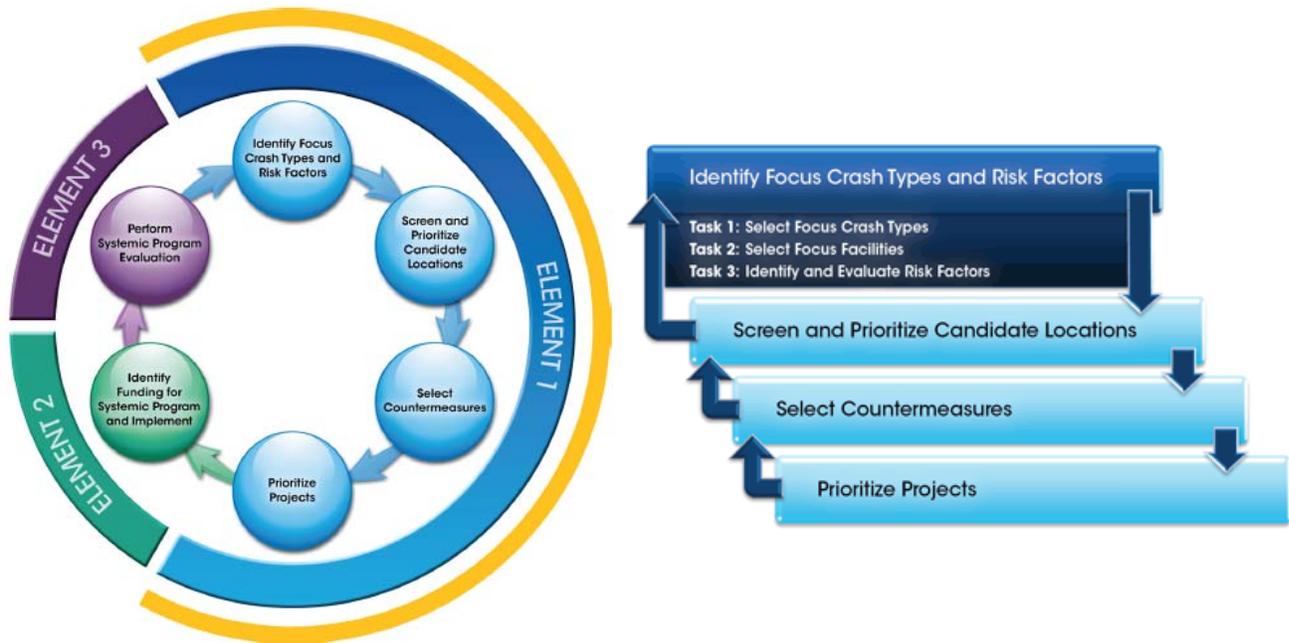
FIGURE 1.2. FHWA's Systemic Safety Project Selection Tool
Element 1: The Systemic Safety Planning Process

The report is divided into five chapters that describe the overall project and findings. *Chapter* 2 includes adescription of the proposed systemic approach. *Chapter 3* details the core elements of the systemic crash matrix and the consideration for the proposed structure. *Chapter 4* presents the countermeasure matrix and the resources that were used to establish the content of the countermeasure table, along with a description of a survey that was conducted to assess the applicability of certain countermeasures to specific locations.*Chapter 5* describes the efforts to incorporate benefit-cost analysis into this approach, as well as consideration for over and under design.Finally, *Chapter 6* presents conclusions and recommendations for further development and implementation of the proposed approach and tool.

2 THE SYSTEMIC MATRIX APPROACH

The approach described in this report is built on Element 1 of the Systemic Safety Project Selection Tool of FHWA's Office of Safety,[3] which provides a systemic safety planning process to: (i) help safety analysts identify priority crash types and associated risk factors; (ii) prioritize alternative candidate locations for systemic safety investment; and (iii) evaluate proven low-cost safety countermeasures.In the course of this project, the research team evaluated the performance of FHWA's systemic tool for pedestrian safety applications, and identified several enhancements to the tool which are described in this report.

The key distinction is that the current study proposes to simultaneously conduct the first two (or three) successive Tasks of Element 1 to produce a systemic crash map in the form of a matrix that shows what types of crashes occur on what types of facilities. The example presented in Figure2.1 showsan example of such a matrix for a major arterial along the California State Highway System (SHS).

The different rows in the systemic matrix represent different crash types, disaggregated by the level of detail available in crash reports (as is addressedin Task 1 of FHWA's approach), while the columns represent different facility types, again, aggregated by level of data available (as is addressedin Task 2 of FHWA's approach). The cells of the matrix are referred to as crash profiles and include the number of crashes that occurred for each crash profile. For example, there were 2 crashes for the crash profile in the top left corner which represents 'Right Turning Vehicle' crashes (crash type 1), on 'Un-signalized, fast, narrow' intersections (location type 1). One added value of this approach is that it provides an agency with a simple to assemble, easy to interpret, transparent snapshot of systemic problems within their networkor study area.

Note that the facility types can be further refined by incorporating risk factors (e.g., AADT, speed limits), as proposed in Task 3 of FHWA's process. Performing these minor modifications early in the process allows more opportunities in the systemic safety planning process without increasing the complexity of the required data or the analysis.

Systemic Crash Map

		Location type								127 Sites
		1	2	3	4	5	6	7	8	
		Unsignalized, fast, narrow	Unsignalized, fast, wide	Unsignalized, slow, narrow	Unsignalized, slow, wide	Signalized, fast, narrow	Signalized, fast, wide	Signalized, slow, narrow	Signalized, slow, wide	
		54	8	8	21	20	7	2	7	127 Sites
Crash type	1 Right turning vehicle	2	0	0	1	10	4	0	3	20
	2 Unsafe speed	0	1	0	0	0	1	0	0	2
	3 Ped right of way; in crosswalk	8	0	1	0	10	2	2	5	28
	4 Ped violation, in crosswalk	2	2	0	0	5	0	0	2	11
	5 Ped violation, not in crosswalk	5	1	0	0	3	1	0	1	11
	6 other	7	2	0	3	6	1	2	0	21
Total number of crashes		24	6	1	4	34	9	4	11	93

FIGURE 2.1. Example of a Systemic Crash Map

The next step of the proposed approach includesa countermeasure matrix of the same dimensions. The countermeasure dimensions would include a pre-filtered set of safety improvements for each matrix cell (also known as the crash profile). For example, the top left cell in the countermeasure matrix would include only countermeasures that can reduce 'Right TurningVehicle' crashes at 'Unsignalized, fast, narrow' locations. A set of attributes, including effectiveness, cost, complexity, and other requirements can be collected for each of the countermeasures. Preparing a countermeasure matrix dimension would result in an overlay of a context-specific engineering toolbox that can address each of the crash profiles of the matrix. Figure 2.2 shows an example of such an application. Each cell would contain a list of the countermeasures that apply to that crash profile.

Each cell of the countermeasure matrix has a list of ID's that correspond to a specific list of engineering countermeasures. For example, countermeasure #6 and countermeasure #7 can be considered for addressing crashes listed in the top left cell. The different shades of green represent the number of countermeasures that can potentially apply to an individual crash profile. Some matrix cells are label 'N/A' which means there are currently no engineering countermeasures that address that specific combination.

Systemic Engineering Improvements		Location type							
		1	2	3	4	5	6	7	8
		Unsignalized, fast, narrow	Unsignalized, fast, wide	Unsignalized, slow, narrow	Unsignalized, slow, wide	Signalized, fast, narrow	Signalized, fast, wide	Signalized, slow, narrow	Signalized, slow, wide
		54	8	8	21	20	7	2	7
Crash type	1 Right turning vehicle	6,7	6,7	7	3,7	1,2,6,7,8,9,10,11	1,2,3,6,7,8,9,10	1,2,7,8,9,10	1,2,3,7,8,9,10
	2 Unsafe speed	6	3,6,11	NA	NA	1,2,6,8,9,10,11	1,2,3,6,8,9,10,11	NA	NA
	3 Ped right of way; in crosswalk	NA	3,11	7	3,7,11	5,8	3,5,8,11	5,8	3,5,8,11
	4 Ped violation, in crosswalk	NA	3,11	NA	3,11	1,2,5,8,9	1,2,3,5,8,9	1,2,5,8,9	2,3,5,8,9,11
	5 Ped violation, not in crosswalk	4,7	3,4,7,11	4,7	3,4,7,11	1,2,4,5,7,8,9	1,2,3,4,5,7,8,9	1,2,4,5,7,8,9	1,2,3,4,5,7,8,9
	6 other	NA	NA	NA	NA	NA	NA	NA	NA

FIGURE 2.2. Countermeasure Matrix

Although beyond of the scope of this project, a more holistic set of improvements can be considered by also including countermeasures that draw on enforcement and education improvements. To accomplish this, a transportation agency would develop a matrix for engineering countermeasures and other matrices for non-engineering activities. While each of the E's can improve safety, implementing them jointlythrough inter-agency collaboration, can better support an agency's pedestrian safety goals.

The systemic crash matrix and the systemic improvements matrix can also play a major role in the overall process. Once established, these matrices can be overlaid using an analytical benefit-cost procedure to determine the locations where proven low cost improvements should be implemented. The specific steps of the proposed approach are not part of the scope of this project, but can be pursued in future efforts.

2.1 DATA SOURCES

Data to populate the matrix is compiled from two main sources—crash data and infrastructure data from Caltrans Traffic Accident Surveillance and Analysis System (TASAS), in addition to data on countermeasures from published state and federal manuals used by Caltrans.

2.1.1 Data for the Crash Matrix

The crash data and infrastructure are each obtained separately from TASAS in raw form and are matched using the standard location attributes as shown in Figure 2.3. Once the crash and infrastructure data are matched, they are used to populate the cells of the matrix with crash frequencies for the factors specified in the columns and rows.
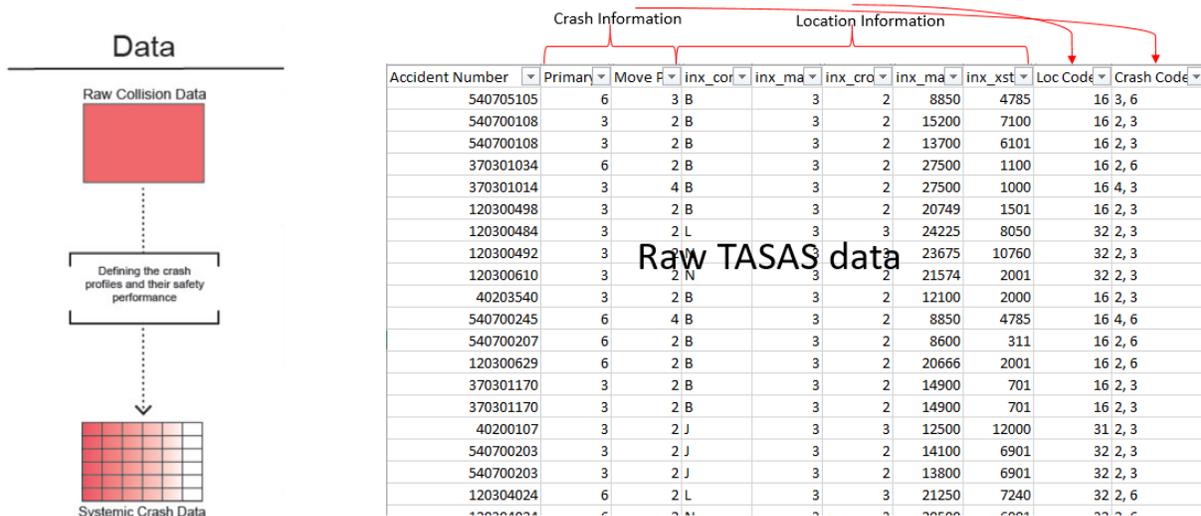

FIGURE 2.3. Data for the Crash Matrix

2.1.2 Data for the Countermeasure Matrix

Thedata for the countermeasure matrix is obtained by examining the attributes of each countermeasure represented in the public manuals to determine where in the matrix a particular countermeasure can address a specific crash profile. The sources used here are listed in Figure 2.4.

Figure 2.4. Sources for the Countermeasure Matrix

3   DEVELOPING THE MATRIX

3.1   THE STRUCTURE OF THE MATRIX

The rows and columns of the matrix define its structure and are determined as part of a trade-off between the desire to have a limited list of countermeasures for each profile, and the operational challenges of having too many rows and columns.
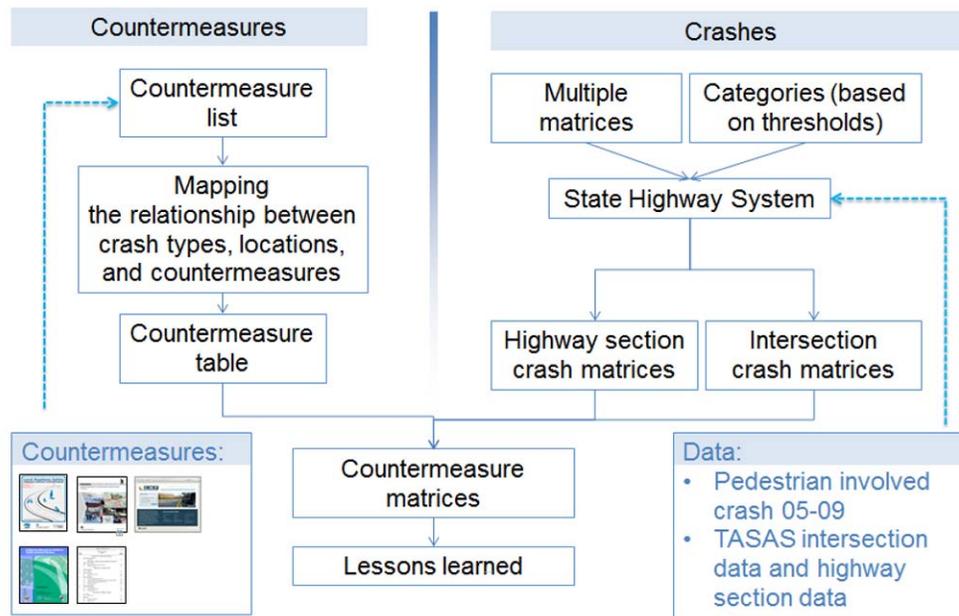

Figure 3.1.Considerations for the Matrix Structure

3.2   IDENTIFYING THE LOCATION AND CRASH TYPE

3.2.1   General vs Specific

As part of this study, different levels of stratification in crash types were explored to determine how they would affect the countermeasures listed in the matrix. General categories use a single factor of the crash, such as unsafe speed or right turning vehicles. As a result, multiple countermeasures apply to each row of crash type. Specific categories combine multiple factors of the crash. Incorporating additional factors into the matrix facilitatesmore holistic assessment of the scenario. The following matrices shown in Table 3.1 are hypothetical examples to demonstrate the concept of how countermeasures may fit into the matrix. In reality, the crash types are likely to show a balance between general and specific categories.

Table 3.1. Different levels of stratification

	Location type 1	Location type 2	Location type 3
Crash type 1	1, 2, 3	1, 2, 3	1, 2, 3
Crash type 2	1, 2, 3	1, 2, 3	1, 2, 3
Crash type 3	1, 2, 3	1, 2, 3	1, 2, 3

(a) General

	Location type 1	Location type 2	Location type 3
Ped action 1, Driver action 1, PCF 1	1	2	3
Ped action 1, Driver action 2, PCF 1		5	6
Ped action 3, Driver action 2, PCF 2	7	8	9

(a) Specific

The advantages of general classification are that the co-benefits of applying countermeasures are more visible, and that it allows the tool to address a broader range of crash types. One disadvantage is that because many countermeasures are likely to apply to a crash type, it is unclear which countermeasures to apply without further research or analysis.

The advantages of specific classification are that it more accurately describes the crash scenario and that it allows identification of targeted countermeasures. One disadvantage is that it is more difficult to select countermeasures that directly address individual crash types. Adding increased specificity to the crash type would narrow down appropriate countermeasures, leaving only the ones that directly address the combination of crash and location types in the matrix. In the exploratory analysis of this study, matrices were created with varying levels of specification to evaluate the outcomes and find a desirable balance.

3.2.2 Location Types and Crash Types

The aim of the systemic approach is to identify a list of suggested countermeasures for the targeted "systemic hotspots"—locations sharing the same risky features. In order to generate the countermeasure lists, information for selecting appropriate countermeasures should be available, thus the research team decided to first analyze the existing pedestrian safety countermeasures to

determine the necessary information for crash and location. Table 3.2 shows some examples of the countermeasure analysis.

Table 3.2. Location Types and Crash Types

Countermeasures	Crash Type	Crash Location		
Install pedestrian countdown signal heads	Single vehicle involved	Signalized intersection	Marked crosswalk	Indicator or not
Install advanced stop bar before crosswalk	Speeding	Signalized intersection	Marked crosswalk	High ped/bike volume
Install ped overpass/underpass	All	Signalized intersection	Marked/ unmarked	Freeway/arterial interx, high vehicle volume, high speed, or rail tracks
Right turn on red restrictions	Ped vs right turn vehicle	Signalized intersection	Marked/ unmarked	Limited sight distance, pedestrian interaction

3.2.3   Urban Roadway Crashes

To determine the categories for the rows and columns, a content analysis of various countermeasure resourceswas conducted to identify the terms that were most commonly used. For location types, speed, crossing distance, vehicle volume, and commercial areas were the most common factors used to describe the application of countermeasures. The TASAS data does not include information about the surrounding environment (for example, commercial, business, or downtown area), so this category was not included in the matrix.

For crash types, the most common factors mentioned were speeding, crossing, and pedestrian visibility. The TASAS data does not include information about pedestrian visibility, however, it does include information about pedestrians walking along the roadway, which wasalso included.

The following matrix shows the crash frequencies for urban roadways.

Urban Roadways		Low AADT	High AADT	High AADT	Low AADT	Low AADT	High AADT	High AADT	Low AADT
		Low speed	High speed	Low speed	High speed	High speed	Low speed	High speed	Low speed
		Short cross distance	Long cross distance	Short cross distance	Long cross distance	Short cross distance	Long cross distance	Short cross distance	Long cross distance
Ped action	Crossing in crosswalk not at intersection	6	5	1	0	2	1	0	6
	Crossing not in crosswalk	137	65	28	11	80	42	21	47
	Walking along roadway	44	398	12	6	30	10	34	6
Driver action	Speeding	11	59	2	0	3	4	2	2

The cells shown in red indicate combinations of crash and location types that can be identified as systemic hotspots. However, when considering the frequency of crashes per lane mile, different combinations of crash and location types emerge as systemic hotspots.

Crashes per lane mile

		Low AADT Low speed Short cross distance	High AADT High speed Long cross distance	High AADT Low speed Short cross distance	Low AADT High speed Long cross distance	Low AADT High speed Short cross distance	High AADT Low speed Long cross distance	High AADT High speed Short cross distance	Low AADT Low speed Long cross distance
Ped action	Crossing in crosswalk not at intersection	0.02	0.03	0.02	0.00	0.02	0.02	0.00	0.13
	Crossing not in crosswalk	0.50	0.39	0.56	0.70	0.68	0.84	0.50	1.02
	Walking along roadway	0.16	2.36	0.24	0.38	0.25	0.20	0.80	0.13
Driver action	Speeding	0.04	0.35	0.04	0.00	0.03	0.08	0.05	0.04
	Mileage	273.84	168.58	50.29	15.73	118.39	50.29	42.3	46.2

When attempting to select countermeasures, some of the cells were observed to have the same set of countermeasures (closer to the general classification example). In addition, some of the cells did not have corresponding countermeasures listed in the resources which were available at the time, yet were identified as systemic hotspots.

Countermeasures

		Low AADT Low speed Short cross distance	High AADT High speed Long cross distance	High AADT Low speed Short cross distance	Low AADT High speed Long cross distance	Low AADT High speed Short cross distance	High AADT Low speed Long cross distance	High AADT High speed Short cross distance	Low AADT Low speed Long cross distance
Ped action	Crossing in crosswalk not at intersection		1, 11		1, 11		1, 11		1, 11
	Crossing not in crosswalk		1, 11		1, 11		1, 11		1, 11
	Walking along roadway	4	4	4, 5	4	4	4, 5	4	4
Driver action	Speeding		12, 13, 16		13, 16, 17	13, 17	16	12, 13	16

Countermeasures	
1	Install ped crossings with signs, markings, signals
4	Install sidewalk/pathway
5	Install raised pedestrian crossing
11	Lane reduction
12	Install ped overpass/underpass
13	Road narrowing
16	Chokers
17	Chicanes, speed humps, speed table

3.2.4 Rural Roadway Crashes

A total of 636 auto-pedestrian collisions occurred on rural arterials(2005~2009). The following matrix shows frequency of collisions in relation to different primary cause types, pedestrian movements, and locationtypes. The top 10 values indicate collisions that largely occurred on arterials, where the design speed is lower than 60mph, and number of lanes to cross is less than 4, especially when the AADT is between 10000 and 30000 pcu. Furthermore, the most common primary was "other violation," pedestrian movement is either "crossing not in crosswalk," or "in roadway."

Table 3.3. Frequency of Auto-Pedestrian Collisions on Rural Arterials (2005~2009)

	AADT	<10000				10000~30000				>30000			
	Design speed (mph)	<=60		>60		<=60		>60		<=60		>60	
	Number of lanes	<=4	>4	<=4	>4	<=4	>4	<=4	>4	<=4	>4	<=4	>4
Primary cause, Pedestrian movement	Failure to yield, crossing in crosswalk at intersection	7		3		43	2	4					
	Failure to yield, crossing in crosswalk not at intersection	2		1		4		1					
	Failure to yield, crossing not in crosswalk	3				4							
	Failure to yield, in roadway					1							
	Other violation, crossing in crosswalk at intersection	4		3		10							
	Other violation, crossing in crosswalk not at intersection					3							
	Other violation, crossing not in crosswalk	48		6		90		30		3		7	
	Other violation, in roadway	46		9	1	57		30	1	1		26	5
	Other violation, not in roadway	2				3		1					

(Note: Red numbers are top 10 values)

Collision rates per lane mile were calculated by dividing the mileage, the new matrix is shown in below. The top 10 values appear evenly for each level of AADT, locations with more than 4 lanes to cross and high collision rate per lane mile. The primary cause and pedestrian movement indicated in this matrix are very similar same to the one above.
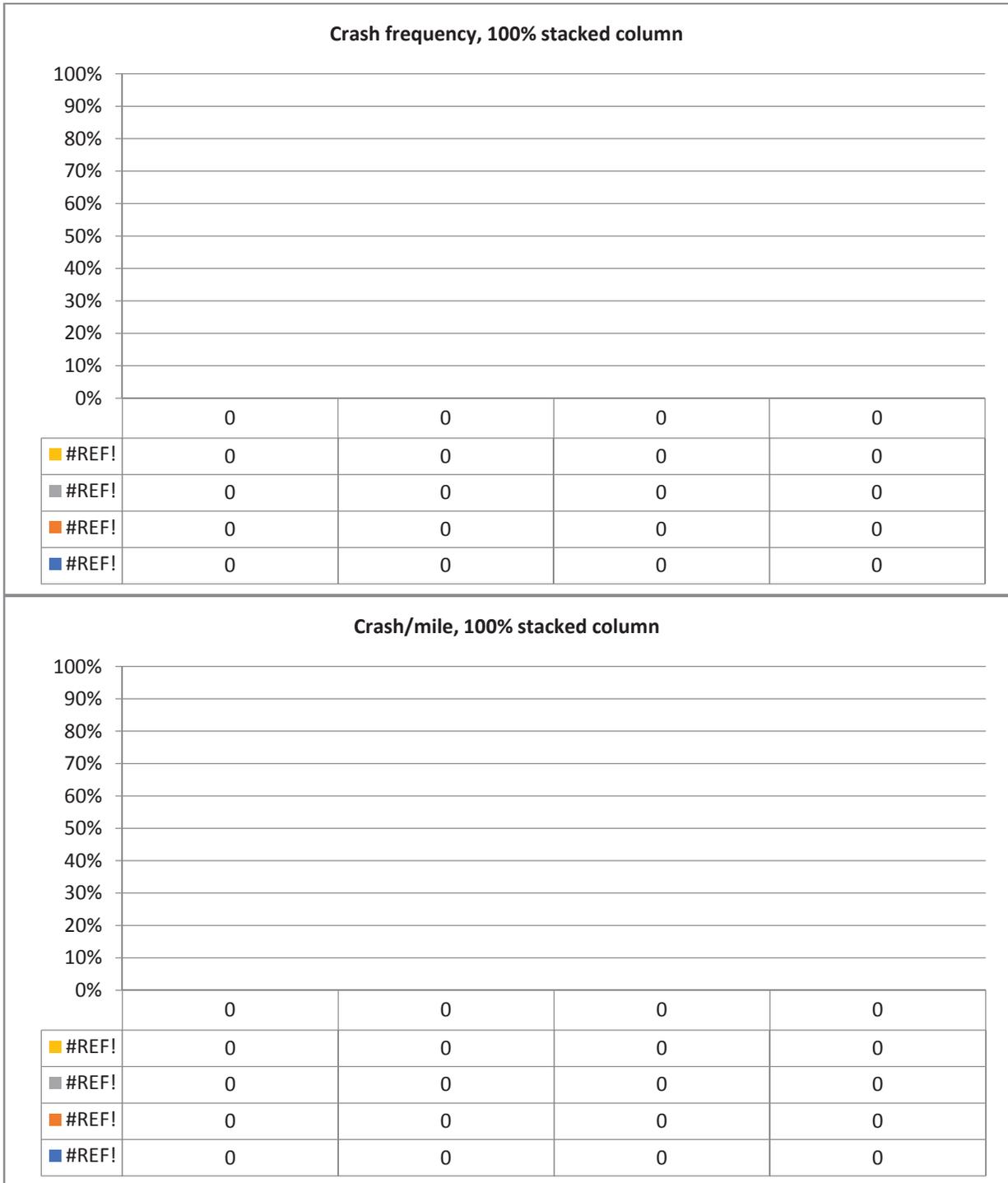
Table 3.4. Rate of Auto-Pedestrian Collisions on Rural Arterials (2005~2009)

	AADT	<10000				10000~30000				>30000			
	Design speed (mph)	<=60		>60		<=60		>60		<=60		>60	
	Number of lanes	<=4	>4	<=4	>4	<=4	>4	<=4	>4	<=4	>4	<=4	>4
	Mileage	201.05	0.00	57.77	0.35	199.50	0.21	97.02	1.17	2.57	0.00	58.02	50.71
Primary cause, Pedestrian movement	Failure to yield, crossing in crosswalk at intersection	0.03		0.05		0.22	9.43	0.04					
	Failure to yield, crossing in crosswalk not at intersection	0.01		0.02		0.02		0.01					
	Failure to yield, crossing not in crosswalk	0.01				0.02							
	Failure to yield, in roadway					0.01							
	Other violation, crossing in crosswalk at intersection	0.02		0.05		0.05							
	Other violation, crossing in crosswalk not at intersection					0.02							
	Other violation, crossing not in crosswalk	0.24		0.1		0.45		0.31		1.17		0.12	
	Other violation, in roadway	0.23		0.16	2.86	0.29		0.31	0.86	0.39		0.45	0.1
	Other violation, not in roadway	0.01				0.02		0.01					

(Note: Red numbers are top 10 values)

However, the above two matrices show different distributions of collisions at location types from the perspective of frequency and rate per lane mile. Therefore, location types should be classified cautiously when frequency is used to build a collision matrix.

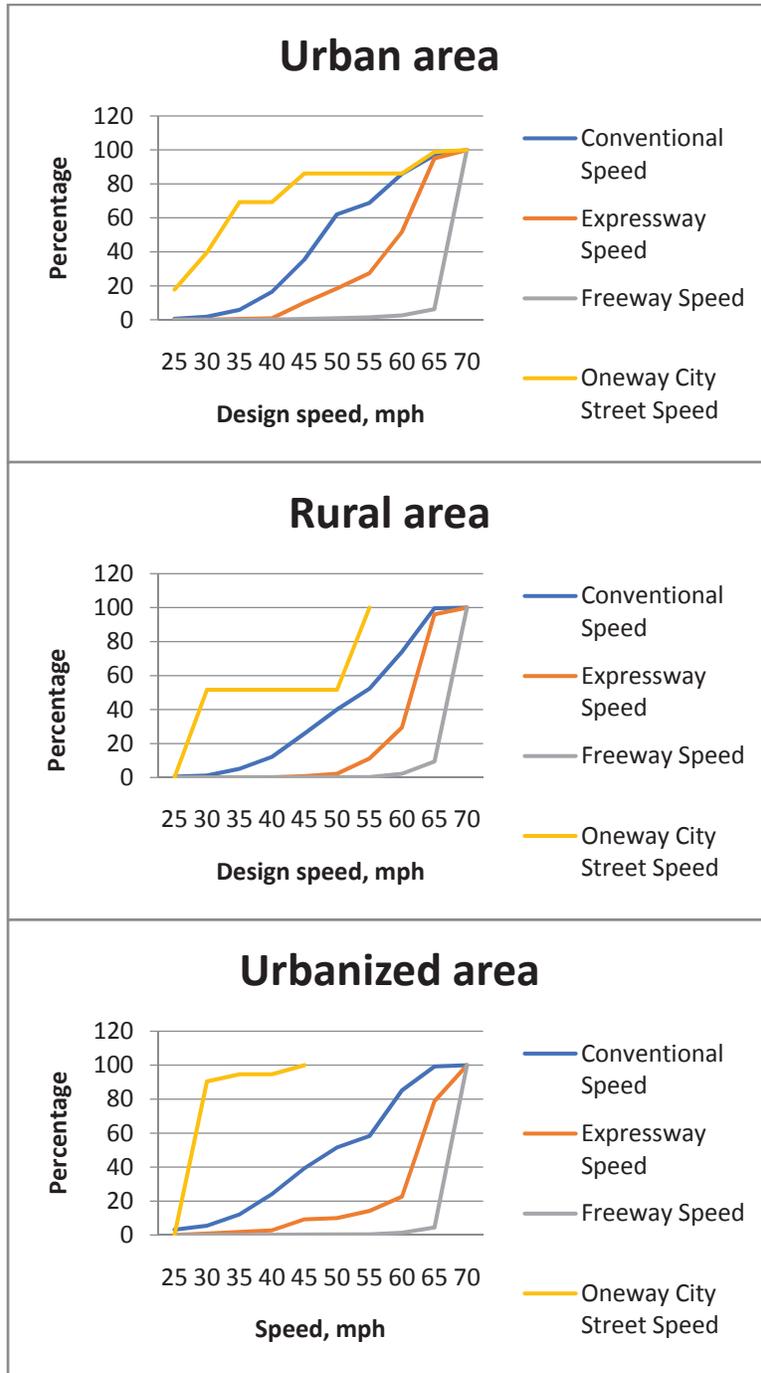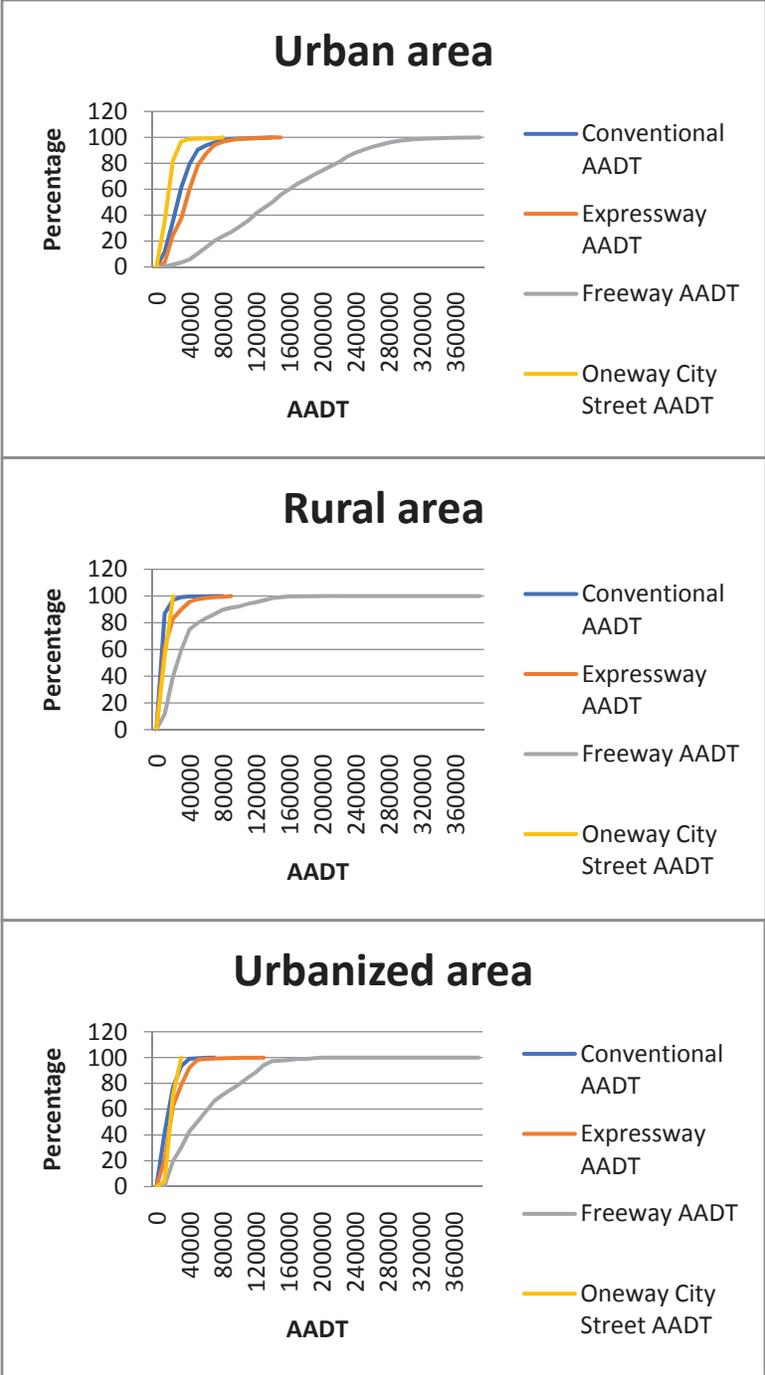### 3.2.5 Separate Matrices for Different Areas and Highway Classes

Crash frequency, 100% stacked column

	0	0	0	0
🟨 #REF!	0	0	0	0
⬜ #REF!	0	0	0	0
🟧 #REF!	0	0	0	0
🟦 #REF!	0	0	0	0

Crash/mile, 100% stacked column

	0	0	0	0
🟨 #REF!	0	0	0	0
⬜ #REF!	0	0	0	0
🟧 #REF!	0	0	0	0
🟦 #REF!	0	0	0	0

Area type vs infrastructure type (crash distribution) 100% stacked column
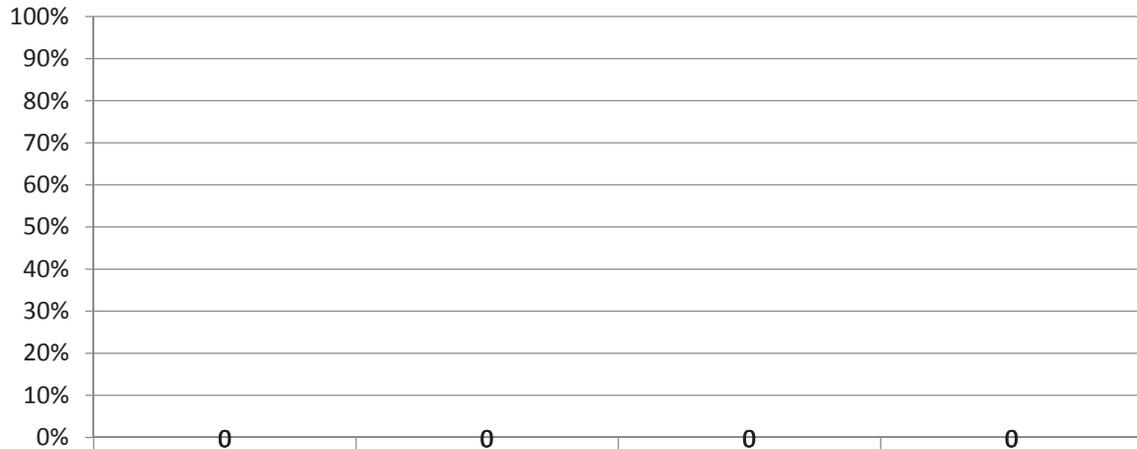
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▪ #REF!	0	0	0	0

3.2.6 Determine the Threshold

Urban area

Rural area

Urbanized area

Urban area

Rural area

Urbanized area

Urban area

Rural area

Urbanized area
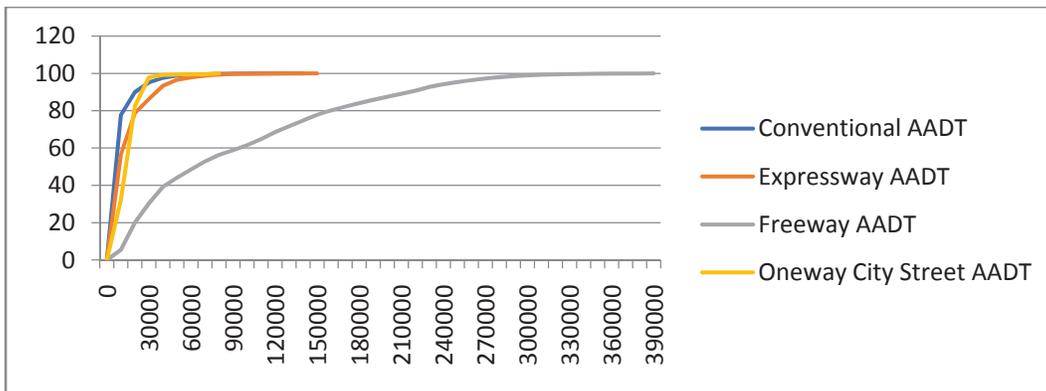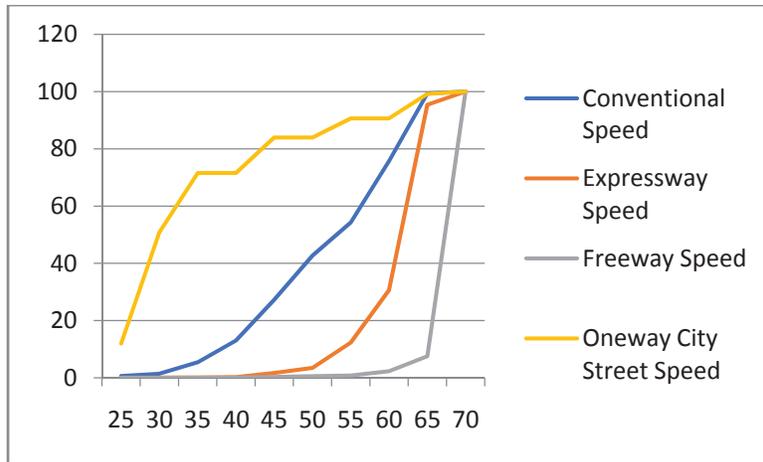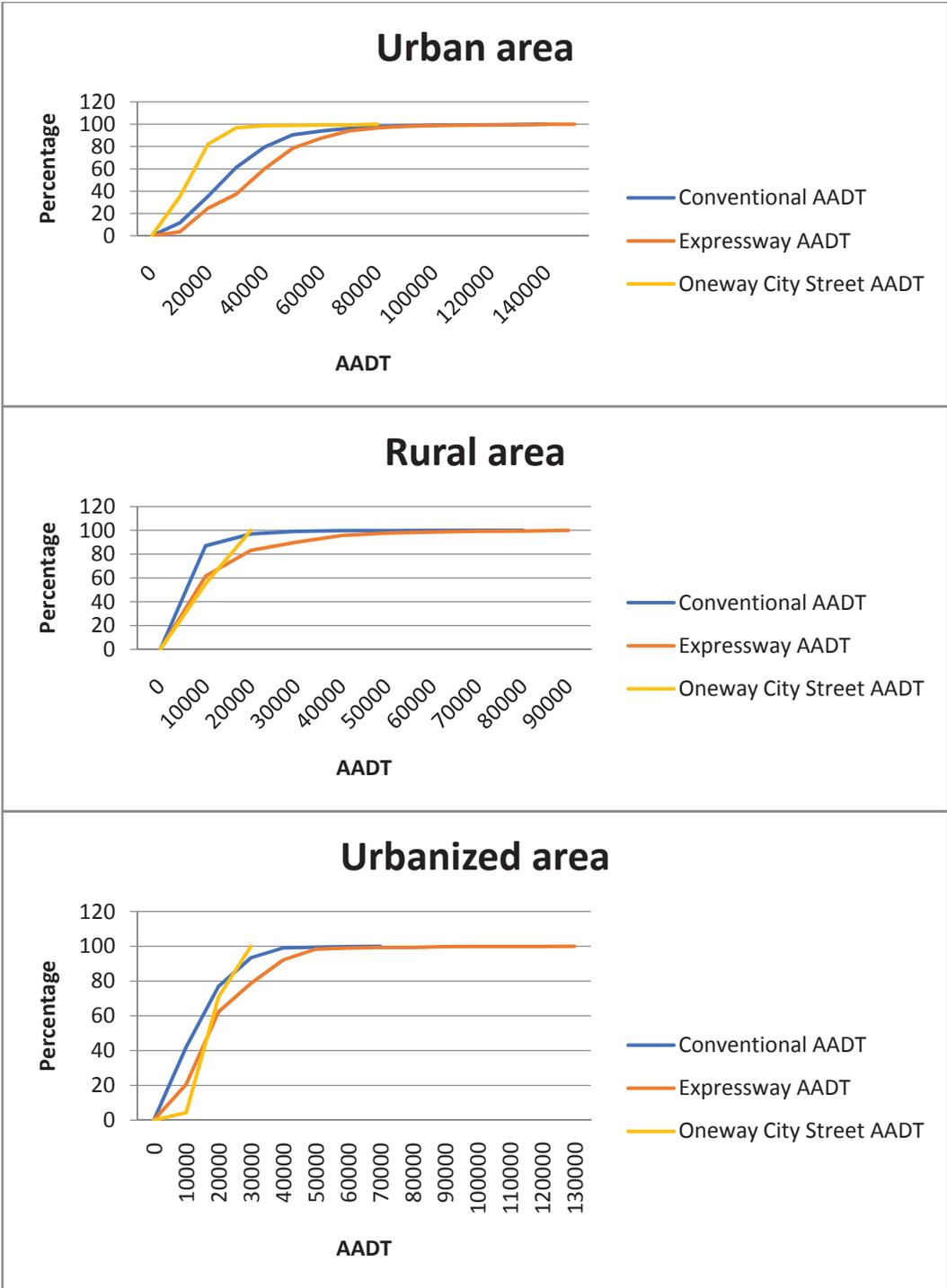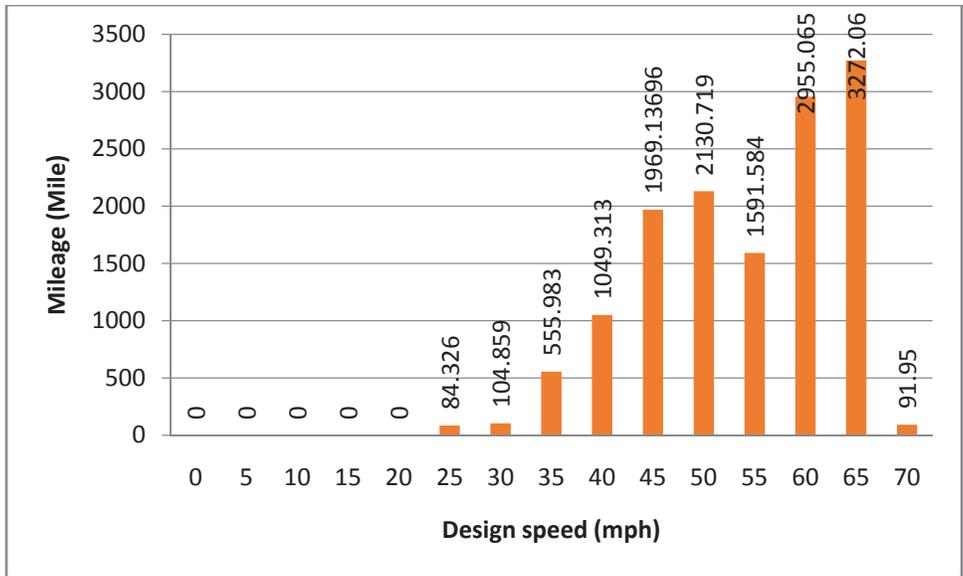
Figure 3.1. Components of a Typical Roadway Segment

4   COUNTERMEASURE SELECTION TOOL

4.1.1   Countermeasure Selection Tool

    1.1. Countermeasure sources
    1.2. Map the relationship between crash characteristics and countermeasures
    1.3. Surveys

Among the summarized countermeasures, there are 19 that need to be confirmed with Caltrans engineers, managers, and investigators regarding the applicability touse on state highways under specific traffic or infrastructure conditions. The research team designed a survey which includes a list of the 19 countermeasures and their questioned conditions. The surveys were sent to the 12 districts in California (see Appendix 2 for a complete copy of the survey).

4.1.2   Crash Pattern Analysis

Step 1. Match collision data (TSAR or TASAS) to the infrastructure data (intersection data, segment data, or ramp data)

Step 2. Obtain the unique (unrepeated) accident number. Note that in collision data, each record is for party, not for collision. Therefore, for further analysis, repeated accident numbers must be removed. To accomplish this:
    1. Choose "U" and "V" in "Party Type" first, this is to filter out the other parties except pedestrians.
    2. Remove the duplicate accident numbers using the tab "Remove Duplicates" in Excel under "Data" panel.

Step 3. Obtain the vehicle information (movement, direction, etc.)
    1. Deselect "L," "U" and "V" in "Party Type." (L is bicycle, U and V are both pedestrian)
    2. Use index function and match function in Excel to match the vehicle movement to each accident number.

Step 4. Extract the useful variables to analyze the crash pattern. Variables are needed are as follows:

Field Name	Description	Note
Primary Collision Factor	Primary collision factor	
Move Preceding Coll	Movement preceding collision	Pedestrian Vehicle
Direction of Travel	Direction of travel	Pedestrian Vehicle
inx_control_code	Intersection control type	
inx_main_lanes_amt	Number of lanes on the main road	
inx_cross_lanes_amt	Number of lanes on the cross road	
inx_mainline_adt	AADT on the main road	
inx_xstreet_adt	AADT on the cross road	
inx_main_left_channel_code	Main left channelization	
inx_main_right_channel_code	Main right channelization	
inx_cross_left_channel_code	Cross lift channelization	
inx_cross_right_channel_code	Cross right channelization	
Rural/Urban	Area type	
Access Control	Expressway, Freeway, Conventional highway, and city one-way street	

Step 5. Remove records with invalid fields.

Step 6. Using the intersection control type, number of lanes on main/cross road, and AADT on main/cross road to select the location types.

Location Feature	Field Name	Value
Signalized intersection	inx_control_code	J - P
Unsignalized intersection	inx_control_code	A - I
# of lanes - Main	inx_main_lanes_amt	<= 3 or > 3
# of lanes - Cross	inx_cross_lanes_amt	<= 3 or > 3
AADT - Main	inx_mainline_adt	< 50,000 or >=50,000
AADT - Cross	inx_xstreet_adt	< 12,000 or >=12,000
Urban and Urbanized area	Rural/Urban	U & B
Rural area	Rural/Urban	R
Expressway and Freeway	Access Control	E & F
Conventional highway and City one-way street	Access Control	C & S

Step 7. According to the direction of pedestrian and vehicle party in a crash, add a field to represent the angle relationship between the two party, either parallel or perpendicular.

Step 8. Investigate the distribution of vehicle's movement and direction in the intersection. Draw arrows to represent the movement, and use different colors to show the number of crashes in that direction.

5   SYSTEMIC COST AND BENEFIT ESTIMATION

5.1.1   Systemic Cost and Benefit Estimate

The aim of this study is to identify the effects of the systemic approach on cost for various countermeasures identified by SafeTREC researchers. A methodology has been developed to identify whether a trend in unit costs vs quantity exists for various countermeasures. In order to make a sound comparison that solely highlights the effect of unit costs vs quantity, the countermeasures in question should be similar to each other except for their quantities produced. Therefore, a comparability scale has been proposed to compare two items. Currently, there are two proposed methods to approach this problem due to data restrictions.

1) Identify the contract items from Caltrans Contract Cost Data that are similar to the items found in the countermeasure list

2) Using the Caltrans data (http://sv08data.dot.ca.gov/contractcost/), list all awarded contracts between the years 2010-2015 for a specific contract item

Example:

		CALTRANS CONTRACT COST DATA			AVERAGE COSTS - 2014	AVERAGE COSTS ADJUSTED TO TODAY	Single Location		Systemic Approach		Comparability Scale	Comparability-Notes
	Countermeasures	ITEM CODE	ITEM DESCRIPTION	UNIT			Quantity	Unit Cost	Quantity	Unit Cost		
1	warning signs for motorists(school advance warning sign, SPEED LIMIT 25 WHEN FLASHING)	566011	ROADSIDE SIGN - ONE POST	EA	$273.90	$265.56	5	$525.61	200	$351.34	3	District 5 - year 2012
2	advanced "STOP" markings	840515	THERMOPLASTIC PAVEMENT MARKING	SQFT	$3.03	$2.83	47	$12	3,750	$5.50	1	District 2 - year 2015

Here, the second item which is the countermeasure "advanced STOP markings" is analyzed. It is matched with the appropriate item "Thermoplastic Pavement Marking" from the Caltrans Contract Cost Database. Two items that were determined to be comparable from the Caltrans database are both from the same district and the same year. Here, the systemic approach shows a reduction in unit costs when the quantity increases from 47 sq. ft. to 3,750 sq. ft. of Thermoplastic Pavement Marking.

3) Plot unit price vs units for that specific contract item (except for the those that have TRO in their estimates) on scatter graphs

Example:
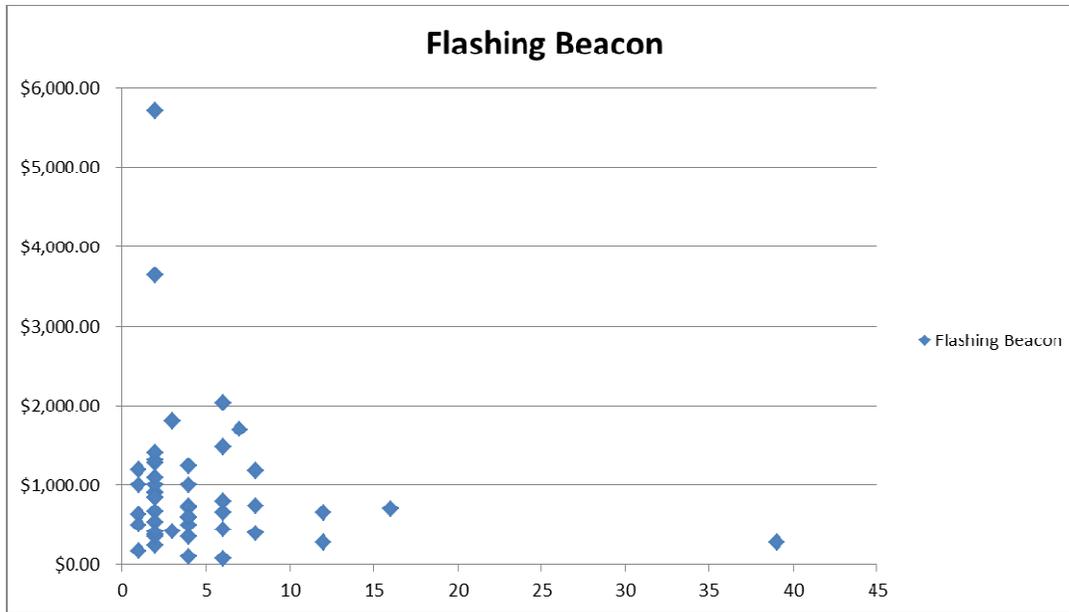
Flashing Beacon

Here the item Flashing Beacon (Item number 120200) is analyzed. Following the methodology explained above, the unit price vs quantity is plotted. This enables researchers to analyze whether a trend in unit costs vs quantity exists.

4) Identify whether a trend in unit price exists with changing units

Comparability scale for contract items (1-Highly comparable, 6-Less comparable)
1) Same district, same year, no mobilization, no TRO**
2) Same district, different years (adjusted prices), no mobilization, no TRO
3) Same district, same year, with mobilization, no TRO
4) Same district, different years (adjusted prices), with mobilization, no TRO
5) Same district, same years, with mobilization, with TRO
6) Same district, different years (adjusted prices), with mobilization, with TRO
*A contract item from a district isn't compared to a contract item from another district because it was noticed that costs highly fluctuate between various districts.
**According to Caltrans, items including Time Related Overhead (TRO) in their estimates might have lowered unit prices. Therefore, items including TRO are not given priority in the comparability scale.

5.2 IDENTIFYING POTENTIAL OVER-DESIGNED INTERSECTIONS WITHIN SYSTEMIC HOTSPOTS

The systemic approach to the identification of crash hotspots and deployment of countermeasures can be further improved by the inclusion of pedestrian exposure data. This additional information can reduce the risk of over-designing intersections. Engineers can over-design an intersection by adding countermeasures to an intersection in a systemic hotspot that does not have sufficient pedestrian volumes to justify the cost of the new countermeasures. In systemic hotspots, there will likely exist some intersections that do not have high pedestrian volumes, or any reported crashes. Those intersections were included in the hotspot identification process because they met the criteria for the intersection design. The chart below shows the mock results of a pedestrian exposure model run on a systemic hotspot of 13 intersections.

Intersections 10-13 may be considered potentially over-designed intersections if a countermeasure is applied, due to the low pedestrian volumes compared to the other intersections in the hotspot.

By identifying intersections with low pedestrian volumes, Caltrans can avoid the deployment of countermeasures where they will see modest use, at best, and they can redeploy limited resources in a way that maximizes safety outcomes. But where does this pedestrian exposure data come from? It is not possible to conduct pedestrian counts at every systemic hotspot intersection after identification process. Some hotspots will include hundreds of intersections. Instead, a pedestrian exposure model is needed to estimate pedestrian volumes at intersections. SafeTREC is currently developing a pedestrian exposure model for the Pedestrian Safety Improvement Program (PSIP), funded by Caltrans. The model uses pedestrian crossing counts at hundreds of intersections across the state as the dependent variable. The explanatory variables includeintersection (e.g., lanes, signalization), land use, and street network characteristics, as well as employment and demographic data about the nearby population. The model should provide useful information about which of these explanatory variables are most closely associated with pedestrian volumes. Model users can then input the most significant intersection characteristics from systemic hotspot intersections to estimate pedestrian volumes at hotspot intersections.

The application of the pedestrian exposure model takes place at the end of the systemic hotspot process. The systemic hotspots must first be identified and matched with the relevant countermeasure first, and then the pedestrian exposure estimates can be added to each intersection and a histogram similar to the one above can be generated to illustrate the intersections in relation to both crashes and pedestrian volumes. The identification of where the over-design threshold is—where it no longer makes sense to deploy a countermeasure due to low pedestrian volumes—is somewhat subjective. The model will not identify this threshold automatically, instead the user will need to look for any obvious drops in pedestrian volumes, in addition to considering the cost of the potential countermeasure.

Over-designed intersections have a logical opposite in systemic hotspots: under-designed intersections. Identified countermeasures for these intersections may not significantly reduce pedestrian crash risk. Under-designed intersections experience the highest absolute number of crashes and pedestrian volumes and pedestrian exposure models are not used when identifying them. Engineers will likely need to use a holistic process to redesign the intersection, and may need to deploy several countermeasures working in concert or develop altogether novel solutions to reduce pedestrian crashes.

Over- and under-designed intersections can help Caltrans continue to maximize their funds to reduce crashes involving pedestrians. This step can easily be added to the existing systemic hotspot process once the pedestrian exposure model is finalized as a part of the PSIP project.

Appendix 1. User Manual

INTRODUCTION

The Systemic Pedestrian Safety Analysis aims to detect a set of locations that share unsafe features associated with particular crash types, and where countermeasures may systematically be installed to improve safety. The selection of countermeasures is based on the nature of collisions as well as on the sites' characteristics. In light of this, a software tool was developed to perform such an analysis. This tool also draws from the activities described under Element 1 of FHWA's Systemic Safety Project Selection Tool (Figure A1).
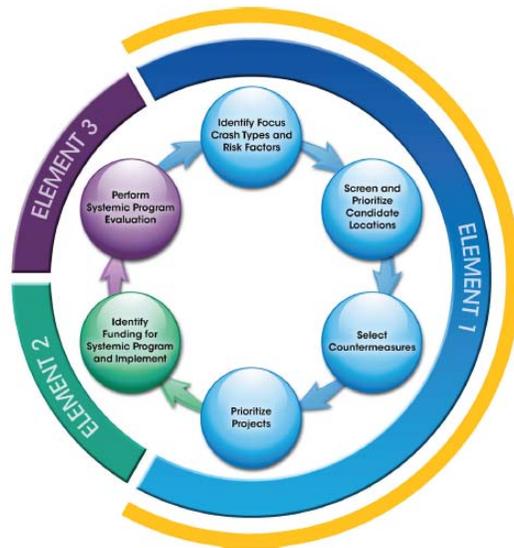
**Figure A1.FHWA's Systemic Safety Project Selection Tool.
Element 1: The Systemic Safety Planning Process**

The first task addressed by this toolidentifies crash types,in addition to their risk factors, and selects focus facilities' features to explain the hazardous situations and locations. Secondly, specific locations are identified for analysis. These sites are recognized as dangerous spots pertaining to the risk factors that correspond to each situation. Next, potential countermeasures are listed based on identified risk factors for each detected systemic hotspot. The countermeasures are evaluated using safety performance functions and other attributes to support practitioners in developing and prioritizing deployment projects.

In particular, to identify the systemic hotspots, a Systemic Crash Matrix is used. The columns in the matrix represent the set of characteristics of the sites such as AADT, number of lanes, signalized or unsignalized, etc. The rows represent crash types enhanced by driver and pedestrian behavior. The crash features are classified by pedestrian movement (crossing elsewhere than in a crosswalk, crossing elsewhere than at an intersection, in roadway, not in roadway, approaching/leaving school bus, etc.) and by primary collision factors (improper turn, speeding, following too closely, influence of alcohol, failure to yield, and other violations). A matrix cell corresponds to the number of crashes of a specific type that occurred in a specific location. In order to build the Systemic Crash Matrix, two sources of information are required. The first is the crash information in the area of interest including the type of crash, collision factor, date and

location. Secondly, data about existing infrastructure are required to enhance the location of each collision with the physical features and to count the available sites that exist for each set of characteristics.

Next, a Countermeasure Matrix is built, in which the columns and rows continue to represent site features and types of crashes respectively. The cells inside the matrix are filled in—or populated—with the countermeasures, representing actions to be taken to address specific crash types in locations that share physical characteristics. To populate the matrix, a list of countermeasures is imported. The list includes the countermeasures, their indexes and Boolean values that apply for every feature treated in the Collisions Matrix: site characteristics and types of crashes. In addition, the list includes cost, benefit and maintenance information for each countermeasure.

THE STRUCTURE OF THE SYSTEMIC TOOL

The presented Systemic Tool facilitates the above-mentioned process and encompasses the following steps:

1. **Data input:**
   a. Import: Collisions and Infrastructure data.
   b. Manipulation: Filter pedestrian collisions and match collisions with the location characteristics from the infrastructure data.

2. **Systemic Crash Matrix:**
   a. Matrix Fill-in: For different districts (from 1 to 12), different areas (urban, urbanized and rural) and different type of roads (conventional, one-way street, freeways and expressways) combinations.
   b. Other Matrix values: Subtotals, total number of sites for each set of features and crash rates (number of crashes/number of locations).
   c. Systemic Hotspots Identification: matrix cells with the highest number of crashes.
   d. Crashes List for a particular cell
   e. Infrastructure List for a particular cell

3. **Countermeasures Matrix:**
   a. Matrix Fill-in: for different districts, areas and type of combination made in the Crashes Matrix.
   b. Countermeasure List for a particular cell

INSTRUCTIONS FOR USE

User Interface

The tool is developed in an Excel macro file approximately 4 MB in size. The macro is programmed using Visual Basic for Applications (VBA) within Microsoft Excel 2010.

The tool is designed to provide the user with a straightforward experience throughout the process. For this reason, a personalized ribbon called SYSTEMIC METHOD was created and added to the usual ribbon group and appears as soon as the file is opened (Figure A2).
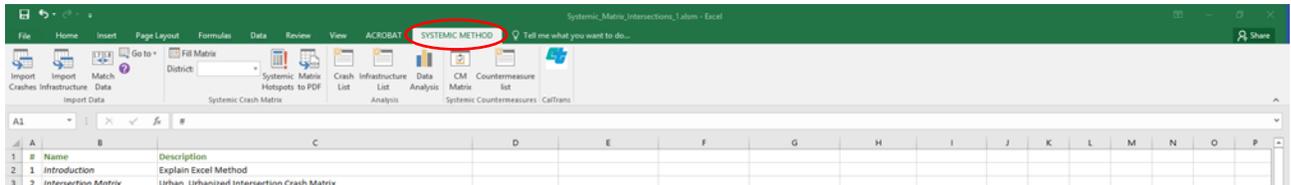

Figure A2.Location of "Systemic Method" Ribbon.

The following figure shows a closer display of the created ribbon and the different groups within it.
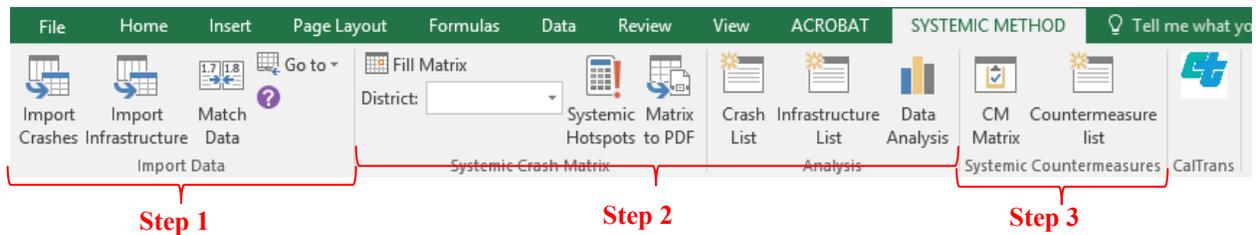
Figure A3. Systemic Ribbon Zoom

Additionally, when the file is opened, four sheets can be seen (Figure A4). The hidden sheets should not be modified by the user since they contain codes to runthe program. The sheet "Sheets_Info" includes a list of all sheets in the file along with a short description. "Data_Import_information" is a sheet in which information about the details of data input is stored. "Intersection Matrix" and "Countermeasure M" are the sheets with the corresponding matrices, which initially are empty. It is mandatory that the user not change the name or the cell locations inside these sheets.
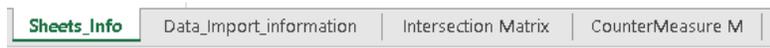
Figure A4.Sheets Available When Initiating File

The following section explains the functionality of the buttons available in the Systemic Ribbon.

STEP 1: IMPORT DATA

As mentioned earlier, two sources of data must be imported: Crashes and Infrastructure. In addition, the two pieces of information should be matched in order to relate the type of crashes with the locations' characteristics. The "Import Data" group includes all of these actions (Figure A5).

**Figure A5.“Import Data” Group**

1. Import Crashes

Click to select which crash data file to import. The program will open a window for the user to select the input file. Next, another window will appear where the user canenter information about the imported data: user name, organization and whether the data is related to intersections or highways (Figure A6). By clicking "OK," the import process will be completed. It is important to note that from the selected file, only the first sheet will be imported. If there are additional sheets in the selected file, these will not be copied into the Systemic Excel file. The imported sheet will be copied under the name Data_Crashes.
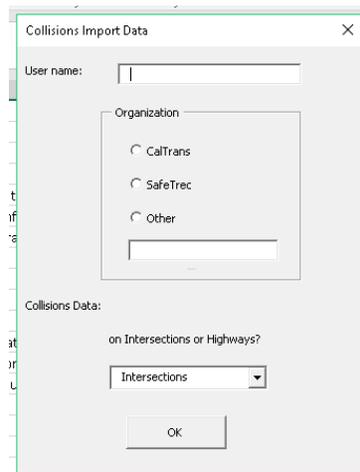
Figure A6.“Collisions Import Data” Information Box

2. Import Infrastructure

The same procedure is followed to import the Infrastructure data. Click to select which infrastructure data file to use. An "Import Data" information window will also appear where the user can enter information about user name, organization and whether the data is related to intersections or highways (Figure A7). The imported sheet will be copied under the name Data_Infrastructure.
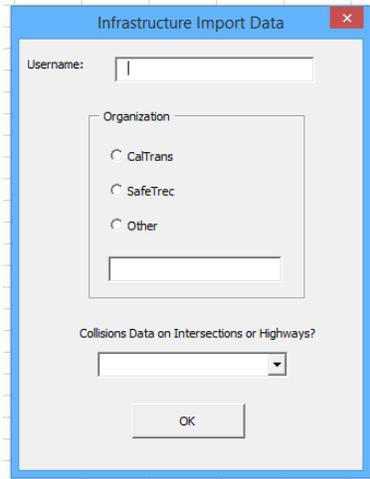
Figure A7."Infrastructure Import Data" Information Box

3. Match the Data

This button matches the crashes and the infrastructure data. The matching is conducted in the backend, and the user will not witness the process but will be informed when the task has been successfully completed when a message box appears (Figure A8). First, the tool creates a unique identification code (ID) for each type of crash and set of infrastructure characteristics. Then, based on these IDs, the crashes rows are matched with the infrastructure information. Finally, a unique code is created to relate the combination of crash-type and infrastructure-type to the position in the Systemic Crash Matrix.
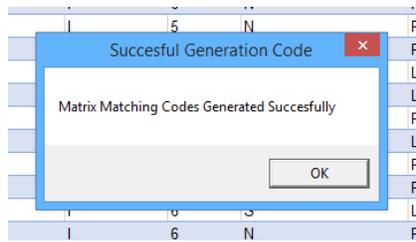
**Figure A8.Successful Matching Data Message Box**

- **Go to**

This optional button was designed for the user to navigate easily through the different sheets: Crash Data Sheet, Infrastructure Data Sheet, Crash Matrix Sheet and Countermeasures Matrix Sheet (Figure A9).
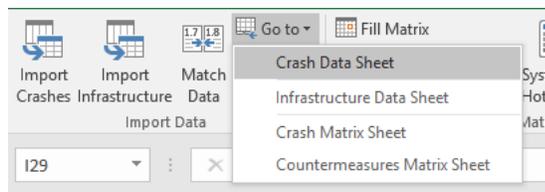
**Figure A9."Go to" Drop-Down List of Sheets**

- **"?"**

By clicking on the question mark, information about the data importing requirements are shown: files' characteristics, column names in the collisions, and the infrastructure data files (Figure A10).
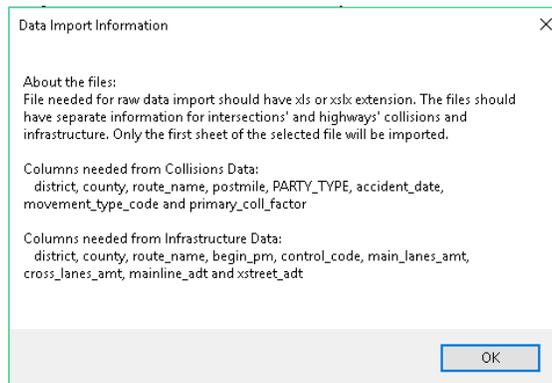
***Figure* A10.*Information* About*Data Import* Message Box**

STEP 2: SYSTEMIC CRASH MATRIX

Figure A11 shows the "Systemic Crash Matrix" and "Analysis" groups included in the Systemic Method ribbon. The button functions are described below.
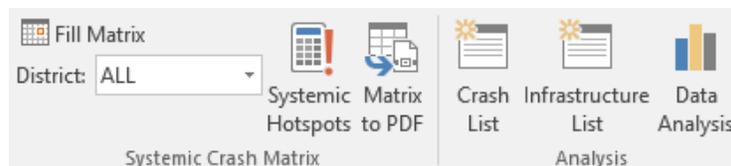
Figure A11."Systemic Crash Matrix" and "Analysis" Groups

- **Fill Matrix**

This function populates the crash matrix with the quantity of crashes that correspond to each crash type in the locations with specific set of attributes (Figure A12). By default, if no district is selected, the matrix will be filled in with the information from all districts, all types of roads and areas. The matrix is automatically formatted to show the results color coded and divided into three percentiles (0%-10% in yellow, 10%-80% in orange, and the highest percentile in red). The cells with zero crashes are set to appear inwhite.

The Fill Matrix button also calculates subtotals of crash types (rows, box A in Figure A12) and location types (columns, box B in (Figure A12) as well as the total number of crashes (box C in Figure A12).In addition, for each location type, the total number of infrastructure sites available in the selected district are counted (box D in Figure A12).

Furthermore, the crash rates are calculated as the ratio between the number of crashes which occurred in a location type and the number of locations that share those attributes (box E, Figure A10).

LOCATION CHARACTERISTICS

MATRIX BODY

CRASH TYPES

Figure A12.Systemic Matrix in the "Intersection Matrix" Sheet

A summary box is located in the bottom-right of the matrix (box F, Figure A12) showing the total number of counted crashes and the number of crashes that were not classified by any crash type and/or location type due to lack of or erroneous raw information (Null crashes). In addition, the summary shows the district number from which crashes were inserted in the matrix, and the conditions related to type of road and type of area are applied to the crashes data to populate the matrix.

If needed, the user can change the zone/are and the type of road and refresh the matrix by clicking the "Fill Matrix" button in the Systemic Ribbon again. Figure A13 shows one of the dropdown lists located in the summary box of the matrix (box F, Figure A12).

Total # of crashes in district	1337
# of Null crashes (not counted)	133
Infrastructure:	Intersections
Zone/Area:	Urban
Type of Road:	Conventional/One-way city street

ALL
Expressway/Freeway
Conventional/One-way city street

Click on 'Fill in Matrix'
If you change this attribute, please click on 'Fill in Matrix' button on SYSTEMIC METHOD ribbon to apply this change to the matrix.

Figure A13.Part of Summary Box of Systemic Matrix to Choose Type of Area and Road

- **District: (dropdown menu)**

As mentioned earlier, the user can create a systemic crash matrix for all districts or for specific districts. To do so, a dropdown menu was developed allowing the user to choose the district number for which to perform the analysis. When the option is selected in the menu, the matrix is refreshed automatically, as well as subtotals, totals and null crashes. A caption of the dropdown menu is shown in Figure A14.
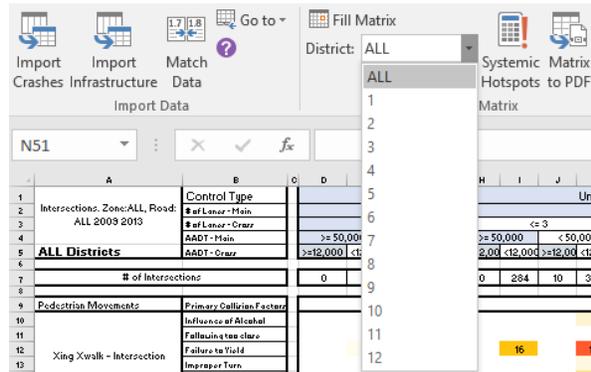
Figure A14.Drop-Down List to Choose District Number, in the Systemic Method Ribbon

- **Systemic Hotspots**

This function highlights the cells with the highest number of crashes. A box will appear in which the user can customize the number of systemic hotspots to display. The systemic hotspots will be colored dark red and will be framed (Figure A16).
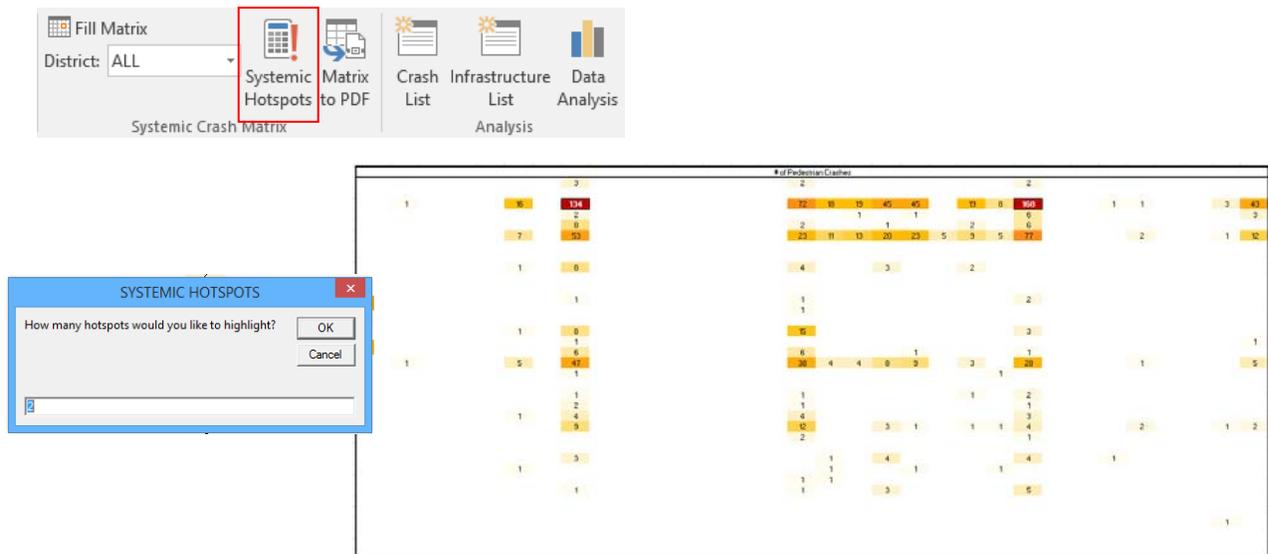
Figure A16.Systemic Hotspot Button from Ribbon. Message Box to Input Number of Hotspots. Matrix with Two Systemic Hotspots Highlighted

- **Matrix to PDF**

This function exports the matrix to a static pdf format and allows the user to choose where to save the pdf file. The default name includes the district number.
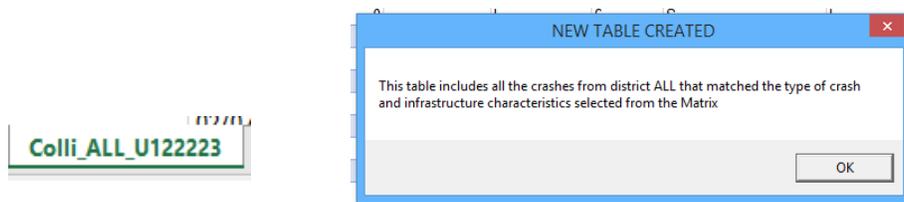
- **Crash List**

The crash list function generates a spreadsheet with a list of all of the crashes in a single cell. After clicking in the "Crash List" button in the Systemic Ribbon, a box appears in which the user can select the cell inside the matrix to specify thedesired list of crashes (Figure A17).
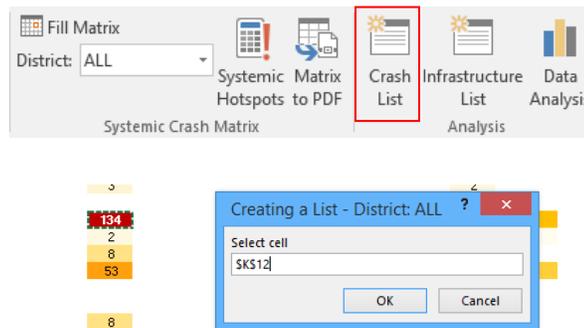
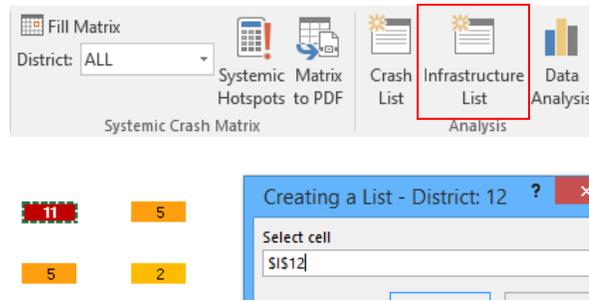**Figure A17.Crash List button in Systemic Ribbon. Message Box to Select Cell**

A new sheet is created which includes all of the crashes that correspond to the selected cell, filtered from the raw data imported at the beginning of the process. The new sheet is named with a suffix of "Colli" for collisions, "ALL" or a number for the district reference and a code that is linked to the type of crash and type of infrastructure. After creating the crash list, a message box affirming the process will appear (Figure A18).

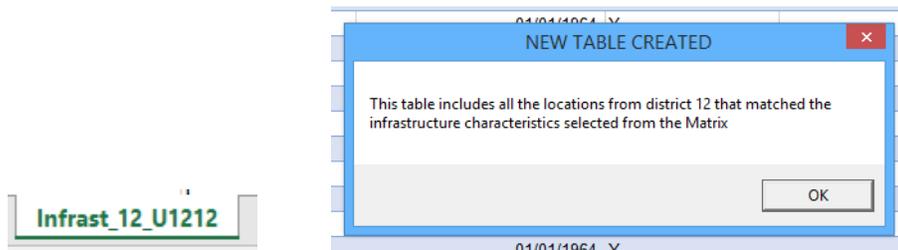**Figure A18. Crash List Sheet Name. Message Box After Creating Crash List**

- **Infrastructure List**

This function generates a spreadsheet including a list of all the locations in a single cell that have the set of characteristics belonging to the corresponding column. Likewise, an infrastructure list can be created by clicking on the button "Infrastructure List" in the Systemic Ribbon (Figure A19). A box also appears in which the user can select the cell inside the matrix from which the sites' features will be obtained to create the list (Figure A19).

Figure A19. Infrastructure List button in Systemic Ribbon. Message Box to Select Cell

A new sheet is added, at the end of which is a list of locations with the corresponding set of attributes. The name of the sheet is formed by a suffix of "Colli" for collisions, "ALL" or a number for the district reference (the example case usesDistrict 12) and a code that is linked to the type of infrastructure (Figure A20). After creating the list, a message box affirming the process will appear (Figure A20).


Figure A20. Infrastructure List Sheet Name. Message Box After Creating Infrastructure List

- **Data Analysis (Disabled for now)**

STEP 3: COUNTERMEASURES MATRIX

After obtaining a Systemic Crash Matrix, the Countermeasures Matrix can be developed. Figure A21 shows the Systemic Countermeasures group present in the "Systemic Method" ribbon. The functions of the two buttons available are explained in the following sections.
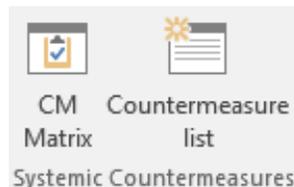
Figure A21."Systemic Countermeasures" Group in Ribbon

• CM Matrix

This function populates the countermeasure (CM) matrix. The numbers in each cell represent the number of countermeasures that can be applied in each type of location basedon crashtype. The matrix is formatted in colors ranging from yellow to green in which cells with a greater number of countermeasures appear in darker green while cells with fewer counteractions appear in light yellow (Figure A22). The district number, the type of road and type of area are the same as those used for populating the Crash Matrix. If desired, the user can change these by modifying them in the Crash Matrix sheet and then calculating that matrix again, before calculating the Countermeasures Matrix using the new conditions.

Intersections. Zone:Urban, Road: Conventional/One-way city street 2009 2013 ALL Districts	Primary Collision Factors	Unsignalized																Signalized															
# of Intersections		0	3	3	28	0	284	10	3659	0	0	0	24	0	5	18	10611	55	49	186	264	14	116	69	1129	0	0	30	41	0	2	36	478
Xing Xwalk – Intersection	Influence of Alcohol	30	32	32	31	30	32	32	31	30	32	32	31	28	31	31	31	30	32	32	31	30	32	32	31	30	32	32	31	28	31	31	31
	Following too close	30	32	32	31	30	32	32	31	30	32	32	31	28	31	31	31	30	32	32	31	30	32	32	31	30	32	32	31	28	31	31	31
	Failure to Yield	27	28	28	27	27	28	28	27	27	28	28	27	25	27	27	27	22	23	23	22	22	23	23	22	22	23	23	22	20	22	22	22
	Improper Turn	16	17	17	16	16	17	17	16	16	17	17	16	14	16	16	16	13	14	14	13	13	14	14	13	13	14	14	13	11	13	13	13
	Speeding	19	20	20	19	19	20	20	19	19	20	20	19	17	19	19	19	13	14	14	13	13	14	14	13	13	14	14	13	11	13	13	13
	Other Violations	30	32	32	31	30	32	32	31	30	32	32	31	28	31	31	31	30	32	32	31	30	32	32	31	30	32	32	31	28	31	31	31
Xing Xwalk – Not Intersection	Influence of Alcohol	25	26	26	25	25	26	26	25	25	26	26	25	24	25	25	25	23	24	24	23	23	24	24	23	23	24	24	23	22	23	23	23
	Following too close	25	26	26	25	25	26	26	25	25	26	26	25	24	25	25	25	23	24	24	23	23	24	24	23	23	24	24	23	22	23	23	23
	Failure to Yield	23	23	23	22	23	23	23	22	23	23	23	22	22	22	22	22	16	16	16	15	16	16	16	15	16	16	16	15	15	15	15	15
	Improper Turn	12	12	12	11	12	12	12	11	12	12	12	11	11	11	11	11	7	7	7	6	7	7	7	6	7	7	7	6	6	6	6	6
	Speeding	16	16	16	15	16	16	16	15	16	16	16	15	15	15	15	15	10	10	10	9	10	10	10	9	10	10	10	9	9	9	9	9
	Other Violations	25	26	26	25	25	26	26	25	25	26	26	25	24	25	25	25	23	24	24	23	23	24	24	23	23	24	24	23	22	23	23	23
Xing – Not Xwalk	Influence of Alcohol	23	24	24	23	23	24	24	23	23	24	24	23	22	23	23	23	22	23	23	22	22	23	23	22	22	23	23	22	21	22	22	22
	Following too close	23	24	24	23	23	24	24	23	23	24	24	23	22	23	23	23	22	23	23	22	22	23	23	22	22	23	23	22	21	22	22	22
	Failure to Yield	20	20	20	19	20	20	20	19	20	20	20	19	19	19	19	19	14	14	14	13	14	14	14	13	14	14	14	13	13	13	13	13
	Improper Turn	9	9	9	8	9	9	9	8	9	9	9	8	8	8	8	8	5	5	5	4	5	5	5	4	5	5	5	4	4	4	4	4
	Speeding	14	14	14	13	14	14	14	13	14	14	14	13	13	13	13	13	9	9	9	8	9	9	9	8	9	9	9	8	8	8	8	8
	Other Violations	23	24	24	23	23	24	24	23	23	24	24	23	22	23	23	23	22	23	23	22	22	23	23	22	22	23	23	22	21	22	22	22
Roadway – Include Shoulder	Influence of Alcohol	14	15	15	14	14	15	15	14	14	15	15	14	13	14	14	14	14	15	15	14	14	15	15	14	14	15	15	14	13	14	14	14
	Following too close	14	15	15	14	14	15	15	14	14	15	15	14	13	14	14	14	14	15	15	14	14	15	15	14	14	15	15	14	13	14	14	14
	Failure to Yield	9	9	9	8	9	9	9	8	9	9	9	8	8	8	8	8	9	9	9	8	9	9	9	8	9	9	9	8	8	8	8	8
	Improper Turn	2	2	2	1	2	2	2	1	2	2	2	1	1	1	1	1	2	2	2	1	2	2	2	1	2	2	2	1	1	1	1	1
	Speeding	5	5	5	4	5	5	5	4	5	5	5	4	4	4	4	4	5	5	5	4	5	5	5	4	5	5	5	4	4	4	4	4
	Other Violations	14	15	15	14	14	15	15	14	14	15	15	14	13	14	14	14	14	15	15	14	14	15	15	14	14	15	15	14	13	14	14	14
Not in Roadway	Influence of Alcohol	33	35	35	34	33	35	35	34	33	35	35	34	31	34	34	34	33	35	35	34	33	35	35	34	33	35	35	34	31	34	34	34
	Following too close	33	35	35	34	33	35	35	34	33	35	35	34	31	34	34	34	33	35	35	34	33	35	35	34	33	35	35	34	31	34	34	34
	Failure to Yield	27	28	28	27	27	28	28	27	27	28	28	27	25	27	27	27	22	23	23	22	22	23	23	22	22	23	23	22	20	22	22	22
	Improper Turn	16	17	17	16	16	17	17	16	16	17	17	16	14	16	16	16	13	14	14	13	13	14	14	13	13	14	14	13	11	13	13	13
	Speeding	19	20	20	19	19	20	20	19	19	20	20	19	17	19	19	19	13	14	14	13	13	14	14	13	13	14	14	13	11	13	13	13
	Other Violations	33	35	35	34	33	35	35	34	33	35	35	34	31	34	34	34	33	35	35	34	33	35	35	34	33	35	35	34	31	34	34	34
Approach/Leave School Bus	Influence of Alcohol	33	35	35	34	33	35	35	34	33	35	35	34	31	34	34	34	33	35	35	34	33	35	35	34	33	35	35	34	31	34	34	34
	Following too close	33	35	35	34	33	35	35	34	33	35	35	34	31	34	34	34	33	35	35	34	33	35	35	34	33	35	35	34	31	34	34	34
	Failure to Yield	27	28	28	27	27	28	28	27	27	28	28	27	25	27	27	27	22	23	23	22	22	23	23	22	22	23	23	22	20	22	22	22
	Improper Turn	16	17	17	16	16	17	17	16	16	17	17	16	14	16	16	16	13	14	14	13	13	14	14	13	13	14	14	13	11	13	13	13
	Speeding	19	20	20	19	19	20	20	19	19	20	20	19	17	19	19	19	13	14	14	13	13	14	14	13	13	14	14	13	11	13	13	13
	Other Violations	33	35	35	34	33	35	35	34	33	35	35	34	31	34	34	34	33	35	35	34	33	35	35	34	33	35	35	34	31	34	34	34

Figure A22.Example of Countermeasure Matrix for Intersections in an Urban Area and for Conventional and One-Way City Streets

The list of available countermeasures and their descriptions can be found in the hidden sheet called "CM list."

• Countermeasure list

After creating the CM Matrix, with the purpose of analyzing a specific cell in detail, the "Countermeasure list" button was developed to generate a spreadsheet with a list of the counteractions that can be taken for the selected combination of location and crash type. Figure A23 shows the message box in which the cell of interest (in this case the cell contains 22 countermeasures to be applied) can be selected.

37
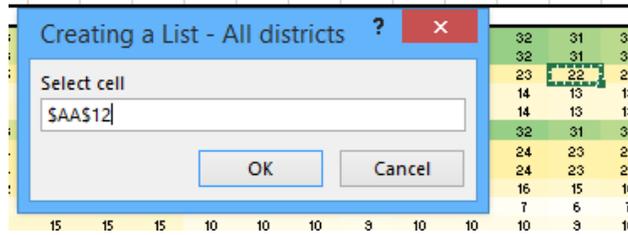
Figure A23.Message Box to Select Cell

This creates a new sheet listing the corresponding countermeasures. Figure A24 shows an example of a countermeasure list. The first rows of the sheet contain the location features of the selected cell, which were used to filter from the list of all countermeasures. Below those are the district reference, the number of locations in that district to apply the listed actions, and the number of crashes (from the Systemic Crash Matrix). The list includes the IDs, description, cost and other performance measures.

Countermeasure List

Location Characteristics	
Main Infrastructure:	Intersections
Area:	Urban
Type of road:	Conventional/One-way city street
Control Type	Signalized
# of Lanes - Main	Long crossing distance
# of Lanes - Cross	Short crossing distance
AADT - Main	Low volume
AADT - Cross	Low volume
DISTRICT	ALL
Number of Locations	1129
Number crashes	135

ID & Countermeasures	Countermeasures	Cost	CMF	Maintenance	Crash Profile	Other1	Other2
11	Curb-extensions	0	0	0	0	0	0
23	Curb radius reduction	0	0	0	0	0	0
3	Marked crosswalks at signalized intersections	0	0	0	0	0	0
53	Adult Crossing Guards	0	0	0	0	0	0
52	School zone signals	0	0	0	0	0	0
44	Advanced stop line	0	0	0	0	0	0
8	Advanced "YIELD" markings	0	0	0	0	0	0
33	Specific paving treatments	0	0	0	0	0	0
40	Automatic pedestrian detectors	0	0	0	0	0	0
13	Move the bus stops to the far-side of crosswalks or intersections	0	0	0	0	0	0
47	On-street parking enhancements (prohibition near crosswalks)	0	0	0	0	0	0
15	Roadway lighting improvements	0	0	0	0	0	0
50	New intersection/crossing lighting	0	0	0	0	0	0
56	Enhance crossing lightings	0	0	0	0	0	0
25	Roundabouts	0	0	0	0	0	0
28	Crossing islands	1	1	1	1	0	0
24	Improved right-turn slip lane design (with refuge islands)	0	0	0	0	0	0
43	Right-turn-on-red restrictions	0	0	0	0	0	0
48	New left-turn channelization	0	0	0	0	0	0
26	Modified T-intersections	0	0	0	0	0	0

CM_list_AA12_

Figure A24.Countermeasure List Example. Sheet Name

The countermeasure list is saved in a new sheet which name is formed by "CM_list" and a code representing the position of the cell in the matrix (Figure A24).

Appendix 2. Countermeasure Survey

A Survey About Countermeasures to Improve Pedestrian Safety on State Highway System In California

Instructions:
First, please read and think about each countermeasure in the table below. Then consider each condition to decide if the countermeasure should be considered as a possible solution to improve pedestrian safety under that condition. Just left- click the check boxes to select the conditions that apply to each countermeasure and write any comments regarding the countermeasure or conditions in the comment boxes to the right. You can select multiple conditions.
Once you have completed the table, please save it as a Word document and email it to _____.

Example:
Look at the example in the second row in the table below. If the suggested countermeasure is "Install advanced stop line," the rationale could be that this countermeasure can reduce multiple threats. Thus, it should be considered for all of the conditions except when there is single lane road because multiple threats can happen only when there are multiple lanes. In the table, you would select all of the boxes except for "Single lane."

CONDITIONS / COUNTERMEASURES (ID & Content)		High design speed (≥45mph)	Low design speed (<45mph)	High volume (AADT ≥50,000)	Low volume (AADT <50,000)	Wide (≥4 lanes)	Narrow (<4lanes)	Single lane	Multi-lane	Median refuge	No median refuge	Comments
Example	Install advanced stop line	☒	☒	☒	☒	☒	☒	☐	☒	☒	☒	
30	Roadway narrowing	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
31	Lane reduction	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
32	One-way/Two-way street conversions	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

CONDITIONS / COUNTERMEASURES (ID & Content)		High design speed (≥45mph)	Low design speed (<45mph)	High volume (AADT ≥50,000)	Low volume (AADT <50,000)	Wide (≥4 lanes)	Narrow (<4lanes)	Single lane	Multi-lane	Median refuge	No median refuge	Comments
33	Intersection median barriers	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
34	Full/partial street closure	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
35	Curb radius reduction	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
36	Improved right-turn slip lane design	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
37	Roundabouts	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
38	New left-turn channelization	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
40	Install raised medians with refuge islands	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
41	Crossing islands	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
42	Curb-extensions	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
43	Mini-circles	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

CONDITIONS / COUNTERMEASURES (ID & Content)		High design speed (≥45mph)	Low design speed (<45mph)	High volume (AADT ≥50,000)	Low volume (AADT <50,000)	Wide (≥4 lanes)	Narrow (<4lanes)	Single lane	Multi-lane	Median refuge	No median refuge	Comments
44	Speed humps	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
45	Gateways	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
46	Specific paving treatment	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
56	On-street parking enhancements (prohibition near crosswalks)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
55	Street furniture	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
54	Landscaping	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	